Chapter 19
Operational Solutions

Section I
Vessel Scheduling or Convoying

19-1. Introduction

Frequent vessel passages through ice-covered navigation channels under frigid conditions generate extra ice. In addition, the passage of vessels causes most of the ice grown along tracks opened by previous vessels to be broken into brash ice, which may collect as thick accumulations that eventually impede vessel movements. Field observations, results from ice-tank (laboratory) experiments, and numerical models have shown that navigation tracks opened by transiting vessels become covered with a rather porous layer of brash ice that is approximately 1.5 to 3 times the thickness of the surrounding sheet-ice cover. The greater the number of passages, the thicker the brash-ice layer is likely to become. In addition to hindering vessels, the accumulations of brash ice may form partial or complete ice jams in the navigation channel itself and parallel ridges beneath the ice cover adjacent to the navigation channel. Ice-tank experiments indicate that these ice jams and ice ridges form especially rapidly in shallow river reaches, where they may extend downward to the bottom of the channel. An additional problem that may affect towboats and barges transiting through level or broken ice is their propensity for entrapping and transporting brash ice beneath their flat-bottomed hulls. Ice-tank experiments have shown that the thickness of the ice accumulations on the flat bottoms of towboats and barges increases with decreasing velocity of the vessels, and also increases when lateral confinement (such as provided by ice ridges along the track) does not allow ice pieces to slide off the vessel bottom toward the sides.

19-2. Operational Choices

The problems outlined above suggest two general approaches for their control and mitigation. The first approach entails the use of mechanical methods for controlling brash-ice accumulations at specific channel locations, either by removal or breakup. Icebreakers could be used to loosen and break up such ice accumulations, and to ease transit conditions for commercial vessels, including towboats and barges. However, no icebreakers currently operate on the Ohio and Upper Mississippi Rivers, or on the Illinois Waterway. The second approach involves the optimum scheduling of tow transits and, possibly, the convoying or grouping of tows, which will minimize ice growth in navigation channels.

19-3. Transit Scheduling or Convoying

Results from laboratory experiments and numerical modeling indicate that the basic rule for minimizing the volume of ice grown in a navigation channel is to minimize the total number of transits or tow passages per day. However, the demands of navigation do not generally allow this to be done. Under the assumption that a certain number of transits must take place per day, numerical modeling has shown that varying the time interval between individual transits has no significant effect on the volume of ice grown. But convoying of vessels, i.e., having tows grouped together to transit one after the other, is a special case equivalent to a large, single transit. Under a convoying concept, only one icebreaking event per day would take place. Correspondingly, the total volume of ice produced in a waterway each winter would be minimized.

a. Limitations. Ice-prone waterways may have relatively short periods of severe ice conditions. The river reaches between locks and dams in many locations are relatively short, resulting in frequent lockages of the tows. The vessels may have numerous and varied origins and destinations along the waterways, some of which may lack adequate docking and mooring areas where several tows could be assembled for convoying. Finally, upbound and downbound transits usually have equal frequency. Under these conditions, elaborate transit scheduling, requiring close coordination among the Corps of Engineers, the Coast Guard, and the navigation industry, is unlikely to be administratively or economically feasible.

b. Guidelines for scheduling or convoying tow traffic. For certain river reaches where ice accumulations are particularly severe, or for a given period when cold weather conditions are extreme, partial scheduling or convoying may be chosen as a temporary, expedient measure to help keep the waterway open and to expedite traffic. In such a convoy, normally the leading towboat would be the most powerful one. It is the vessel most likely to be able to do the required icebreaking in the difficult areas. It may also involve the widest tow configuration, thereby opening the navigation channel for the rest of the tows in the convoy. Finally, the most powerful boat may be capable of sustaining a speed sufficiently high to avoid ice accumulations underneath its own barge bottoms, as well as those of the following tows. The size of a convoy may be limited by the time required to pass it through a lock, rather than by the time required to move between two successive locks. While transit scheduling or convoying are not common approaches to alleviating winter transit difficulties in the navigable waterways of the northern United States, they should be considered when extraordinary local and short-term ice conditions are forecast or are at hand.

Section II
Operational Techniques at Locks and Dams

19-4. Introduction

Operational techniques to mitigate ice-related problems at locks and dams tend to be site-specific. Factors influencing the success of any operational technique include the geographical location of the project with respect to river features, the river system that the project is on, the location of the dam in relation to the lock, the presence of an auxiliary lock, the kinds of gates at the lock or dam, the presence or absence of an effective high-flow air system at the lock, the availability of a work boat assigned to the lock, the prevailing wind direction, the amount of winter navigation, and so on. The general problems caused by ice at locks and dams are summarized in Chapter 14: ice obstructing the upper lock approach, fragmented ice floes accumulating in miter gate recesses, ice adhering to lock walls and miter gate recess walls, inoperative floating mooring bitts, vertical check pin (line hook) icing, ice accumulating in the lower lock approach, difficult ice passage at dam spillway gates, ice buildup from spray at dam spillway gates, icing from leakage at gate seals, and ice accumulating on intake screens.

19-5. Physical Ice Removal

Several of the ice problems at locks and dams involve ice adhering to structure surfaces. When methods for the prevention of these ice buildups are not available, it may become necessary to resort to physical removal techniques.

a. Mechanical contact tools for ice removal. Two hand tools that can reliably be used to remove ice from concrete or steel surfaces are the pike pole and the ice chipper. Both of these tools are widely used by lock personnel at sites that experience winter icing problems. Figure 19-1 is a sketch of an ice chipper that has been refined over many years by its users. Large mechanical equipment used to scrape ice collars from lock walls is limited. Backhoes scrape the wall vertically by drawing the bucket teeth up the face of the concrete. With a light machine, this may require more than one pass to scrape through to the concrete, and frequent repositioning of the machine is necessary. With a heavier track-mounted machine, a single pass is usually sufficient. It is easy to move the machine along and there are no spuds to be set. However, with forceful operation, damage to the lock wall is inevitable, and the concrete on grooved or paneled walls could be seriously spalled.

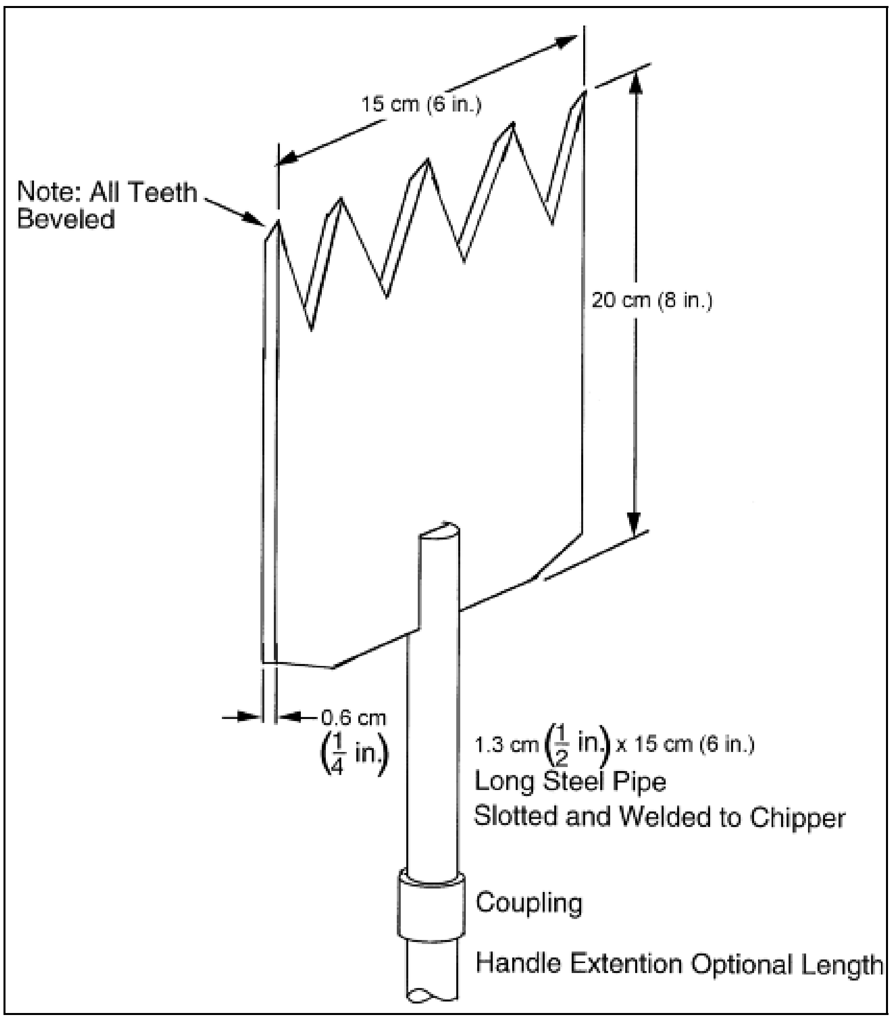

Figure 19-1. Effective design for a manual ice-chipping tool

b. Ice removal with noncontact tools. Two techniques for ice removal using noncontacting tools are steam and water jets. Steam, when available at the desired locations, has always been used, often via lances or pipe probes placed and maneuvered by hand. But using steam is slow and time-consuming. The use of high-pressure water jets is rare because of the high horsepower required and the bulkiness of the typical systems. Advances in the design of such systems could make them more attractive.

19-6. Methods Used at Locks

Operational techniques used to mitigate ice problems at locks are briefly listed below. The list of practices can always be enlarged by discussing any particular problem with the lock or maintenance personnel at neighboring project sites.

a. Upper approach. Techniques to reduce upper approach ice problems include using an auxiliary lock with a bulkhead spillway to pass ice, ice lockages in the main chamber or an auxiliary chamber, diagonal high-flow air-screen deflectors, and towboat wheel wash. Other possibilities are the placement of barge traffic awaiting downbound lockage in appropriate configurations to deflect ice, using ice spillways near dams (if present) or using dam gates to pass ice, assuming sufficient flow is available for this purpose.

b. Miter gate recesses. To clear fragmented floes from around miter gates and recesses, towboat wheel wash, miter gate fanning, pike poles and ice rakes, or recess air flushers are used. If the techniques used to deflect floating ice away from the upper approach are effective, then the task of dealing with fragmented ice in the lock chamber and gate recesses will be reduced.

c. Lock walls and recess walls. Ice accumulations or ice collars on lock walls and miter gate recess walls cause width restrictions, as noted earlier. To remove ice collars, or to prevent or reduce the ice growth, various techniques can be considered. If the pool elevation in the chamber is kept high except during lockages, the chamber wall temperature will be near the water temperature. On the other hand, if the pool is kept at a low level, more of the lock wall is exposed to the subfreezing air, allowing the wall to reach temperatures below freezing and thus allowing more ice to form. Removal of the ice is critical in the gate recess area. Common practices at many locks are the labor-intensive ones of using chippers, pike poles, and steam lances. Other techniques that may be available include low-flow bubblers, surface-mounted heat mats, embedded circulation loops of warm fluids, and mechanical tools like backhoes.

d. Mooring bitts. Floating mooring bitts typically freeze in place because of floating ice being pushed into the bitt recess area, as well as because of ice buildup on tracks and related rollers. Currently, personnel at many locks secure the bitts in the top position, not using them during the winter months. This, of course, leaves the bitts unavailable while lock traffic may still be in need of them. The techniques of using a single-point air bubbler or replaceable embedded electric heaters have been developed but are not yet widely adopted. Additional safety systems should be added so that if a floating bitt becomes frozen in the submerged position, it will not be launched skyward when the ice melts.

e. Check pins. Vertical check pins are typically iced over and are forgotten until spring. Lock personnel rely on mooring points on the top of the lock wall to secure the lines during the winter months. Constant monitoring of the lines by deck hands is required. No operational technique appears feasible, other than steaming or chipping the ice on the check pins.

f. Lower approach. The final lock ice problem is the accumulation of ice in the lower approach. Typically, this is not a serious problem for lock personnel. It is possible to stage tows waiting to be locked up in such a manner as to block the encroachment of ice. Water discharge when lowering the lock chamber level helps to clear the immediate lower approach area.

19-7. Methods Used at Dams

Operational techniques used to handle the icing problems associated with dams are much the same as those used at locks. Comments on specific practices at dams are given here. Many dams have been equipped with embedded electrical heaters along gate sealing surfaces. Unfortunately, these heaters have a record of frequent failure, and a new technique has been designed for the installation of a removable heater that is easily exchanged if it becomes inoperative (see paragraph 18-16*a*). Steam lances are commonly used in dam deicing. This is a time-consuming operation but it can be effective. Cindering the dam gate seals (i.e., applying coal cinders to the water above the gate, which then flow toward and plug the gaps at the seals to reduce water leakage) helps to prevent the formation of larger ice deposits on the downstream side of the gate. A new method that has been proposed is a heater inserted in the hollow channel of a J-seal to keep the seal material flexible (see paragraph 18-16*c*). The increased flexibility makes a better seal, eliminating or reducing leakage and ice formation on the downstream side of the gate. The types of gates and their lifting devices are largely site-specific, and techniques used to operate them in winter are developed with time and experience. Typically, submergible gates operated in the submerged position have the fewest operational problems from ice during the winter months. Problems experienced with submergible dam gates are identified in *Submergible Gate Use Within the Corps: Case Histories* (U.S. Army 1985). In many instances, operational techniques now used by lock and dam operators are also described in that report.

Section III
Operational Use of Thermal Resources at Locks and Dams

19-8. Introduction

There is often interest expressed in making beneficial use of energy or thermal resources that may already be present in the vicinity of navigation projects. By this is meant either energy introduced into waterways by man-made sources, or energy that might be extracted from the natural environment (the latter sometimes being called unconventional energy sources).

19-9. Man-Made Energy Sources

Man-made sources of warm water on rivers are often present that either already suppress some ice formation or may be used to cause some ice suppression. The most significant source is the release of cooling water from thermal power plants, which amounts to 150 to 200 percent of the energy produced as electricity. Another source is the release of water from reservoirs that contain slightly warmer water at depth, such that downstream flows may be several degrees above freezing. In addition, there are other less significant sources such as the discharge of treated sewage and warm waste water from industrial processes. While direct application of these thermal energy resources at navigation projects may be difficult, their effects may be helpful in diminishing ice problems in the vicinity of locks and dams. For a complete analysis of the effects on ice covers produced by these thermal energy sources, see Chapter 3, *Ice Control*, paragraphs 3-8 and 3-9.

19-10. Unconventional Energy Sources

Conventional energy sources, such as electricity from public utilities, or the burning of hydrocarbon fuels for heating (either direct heating, or indirect heating such as for generating steam), can be viewed as comparatively expensive sources of energy for ice control at lock and dam installations. Therefore, consideration has sometimes been given to unconventional energy sources, such as sensible heat from groundwater, heating of a transfer medium by solar energy, or electricity generated from wind energy. A study was conducted during the River Ice Management Program to evaluate the feasibility of using energy from either groundwater, sunlight, or wind to achieve typical ice removal or ice prevention tasks at lock and dam projects (Nakato et al. 1988). In general they found that there is very little promise in pursuing the development of the unconventional energy sources that were examined (groundwater, solar energy, or wind energy). The study concluded that none offered great promise over other more conventional means of ice control at locks and dams.

a. Groundwater heat. Heat energy in groundwater appears to be an attractive energy source. Groundwater is readily available in the vicinity of most rivers. Its temperature is generally near the average annual air temperature for any particular site, meaning that it is well above 0ºC (32ºF) for nearly all of the inland waterways of the conterminous United States. But the appeal of groundwater is diminished by practical problems involved in extracting and applying its heat, and by the fact that, in the colder areas where heat energy is needed most, the groundwater temperatures are lower. Several approaches for applying the heat contained in groundwater were investigated for preventing or relieving ice buildup on lock components. Both the method of whole-lock heating and the method of heating the water adjacent to the lock walls were ruled out almost immediately as requiring unreasonable amounts of energy. Only the method of circulating warm groundwater through pipes embedded in lock walls to raise the wall temperature was close to being practical. This approach features heating the mass of the walls first, which then lose the heat energy to the air. A significant drawback is that the mass of the walls absorbs so much heat as to make the approach unattractive.

(1) Assume that groundwater at 14ºC (57ºF) is flowing through an embedded pipe, and the pipe-wall temperature is constant at 0ºC (32ºF) throughout its length. This simulates the pipe being embedded in a lock wall that is massive compared to the pipe, and in the vicinity of 0ºC (32ºF) throughout its mass. Two sizes of pipe and two flow amounts for each size were analyzed. Table 19-1 shows how much energy is transferred from the groundwater to the surroundings of the pipe (i.e., the lock wall mass) in a pipe length of 61 meters (200 feet). Also shown is the temperature of the groundwater at the end of the 61-meter (200-foot) run.

Table 19-1
Energy Transferred by Groundwater to Lock Wall

Pipe Size cm (in.)	Flow per Pipe L/s (ft^3/s)	Energy Transferred in 61-m (200-ft) Pipe Run (kW)	Water Temperature at end of 61-m (200-ft) Pipe Run ºC (ºF)
2.5 (1)	0.63 (0.022)	37	0.1 (32.2)
2.5 (1)	0.95 (0.033)	57	0.2 (32.4)
5.1 (2)	2.52 (0.089)	136	1.2 (34.2)
5.1 (2)	3.79 (0.134)	200	1.4 (34.5)

(2) Note that the values in Table 19-1 are just to keep the pipe-wall temperature at 0ºC (32ºF). The real case would be to keep the temperature of the lock wall at or above 0ºC (32ºF); consequently, even larger flows and energy transfers would be needed. Depth of pipe embedment and pipe spacing would be important factors in determining how much larger the flows would have to be. Also, note that if the groundwater was at a lower temperature or moving at lower flow rates, or both, there could be danger of freezing near the end of a 61-meter (200-foot) pipe run. This would indicate the need for shorter pipe-run lengths.

(3) An operational application of embedded pipes would call for several parallel pipes running horizontally at the ice-collar location on the wall, each pipe run having a length of, say, 200 feet, and with the pipes being placed end-to-end with other pipes to cover the entire lock length. The example values above indicate that unless the groundwater temperature is very high, water temperatures decrease toward 0ºC (32ºF) too quickly (i.e., in too short a distance in the pipes) for this technique to be practical. It appears that other heat sources, such as steam or electric heating, may be more attractive for embedded wall heating systems.

b. Solar energy. In general, the study found that the use of solar energy to assist in keeping lock and dam installations ice-free in winter was not practical. From assumptions based on using standard types of liquid-heating solar collectors, and three values of incoming solar radiation typical of clear-sky daily averages during winter in the Upper Mississippi and Ohio River basins, efficiencies and temperature increases in the heat-transfer liquid were calculated. Efficiency drops markedly as air temperature decreases. In addition, cloudy days, the requirements for storage of heat (to make it available when needed, such as at night), and the capital costs of very large collectors and associated equipment all would combine to discourage extensive consideration of solar energy for lock ice control, in view of the performance levels that can be anticipated.

c. Wind energy. For most locations, normal fluctuations in wind make extraction of its energy unreliable unless some means of energy storage is available. Theoretically, the immediate power output (without storage) from a wind turbine is proportional to the third power of wind speed. Practically speaking, wind turbines often are subject to system controls to minimize the difficulties of extreme variability of power output. In any case, sample calculations illustrated the amounts of power potentially available from wind. For many locations on the inland waterways, an average winter wind speed may be represented by 14.5 km/h (9 mph). A wind turbine having 6.1-meter (20-foot) diameter blades and operating at 50 percent efficiency in this wind condition can generate an average power output of about 0.6 kilowatts, according to commonly used formulas. This means that five or six such wind turbines would be needed to provide power for continuous operation of the comparatively small (3.0 m^2 [32 ft^2]) lock-wall heating panels discussed in paragraph 18-16*b* and shown in Figure 18-12. As with solar energy, the variability of the energy source and the capital costs of the installations and equipment combine to make wind energy use for ice control at locks unattractive.

19-11. References

a. Required publications.

None.

b. Related publications.

Nakato et al. 1992
Nakato, T., R. Ettema, and K. Toda 1992. *Unconventional Energy Sources for Ice Control at Lock and Dam Installations*, Special Report 92-13, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.

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U.S. Army 1985. "Submergible Gate Use Within the Corps: Case Histories," Report to U.S. Army Cold Regions Research and Engineering Laboratory, June 1985; prepared by U.S. Army Corps of Engineers, Louisville (Kentucky) District.